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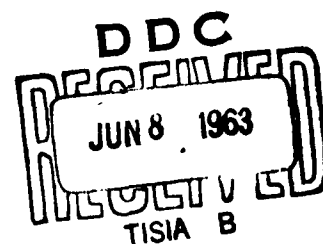
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AN APPROACH TO THE STUDY OF A DEVELOPING ECONOMY  
BY OPERATIONAL GAMING

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AN APPROACH TO THE STUDY OF A DEVELOPING ECONOMY  
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1. INTRODUCTION

This paper considers the possible use of operational gaming, or simulation involving human players, to examine an economy as a whole. It is our belief that this operations research technique could become an extremely useful tool for the study of a developing economy. In the present state of the art, however, it is not going to provide, with confidence, direct recommendations on what to do about matters of national policy. Rather it is an educational device, providing both ideas and insights, useful for the generation and preliminary comparison of alternative economic policies.

Operational gaming, like other operations research techniques, undoubtedly is most fruitful when applied with a clear objective in mind to well-structured problems based on abundant data. Such a situation is more likely to be found within an industry or a single firm. Nevertheless, our present discussion of gaming techniques will be entirely

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in terms of their applications to national economic planning. We believe this approach to hold a greater promise in this difficult area than any other available technique.

## 2. THE ROLE OF OPERATIONS RESEARCH

In principle, the problems to which Operations Research may be applied in the economies of the so-called developing countries are similar to and no more challenging than their counterparts in the highly developed countries. On the other hand, while, in the highly developed countries, custom, the belief in laissez-faire, and the vast intricacies of the national economy ordinarily restrict the applications of Operations Research to the "tactical" scale of economic planning within an industry or a firm, the less sophisticated structure of a newly emerging economy and a greater faith in planning greatly enhance the chances of employing Operations Research on a "strategic" level. One may even hope that, if Operations Research could be successfully applied to the analysis of developing economies, the insights gained might provide useful leads concerning the application of similar methods to more highly developed nations. Thus analysts primarily interested in the exploration of highly sophisticated national economies may be well advised to divert some of their attention to the study of more primitive economies and to use the experience gained in modeling the latter to achieve

eventual progress in predicting economic effects in more intricate contexts.

Before planning can be applied effectively on a national scale—say, to do long-range resource allocation for the general advancement of an emerging economy or to determine foreign-aid policy for such an economy—it would seem to be a clear prerequisite that the planner have a thorough understanding of how the economy works as a whole, not merely how it works on an institutional or on an industrial scale. One would want to be able to predict, for example, how economic measures, applied nation-wide, such as tax cuts, or subsidies, or price controls, or tariffs or interest rates, would influence the workings of the economy as a whole and how they would differentially affect the various sectors of the economy. Unfortunately, such predictions cannot be made with great assurance. Most economists attribute the difficulties to the many factors and complex relationships involved. Some, however, feel this is due to the lack of a consistent theory.\*

If an adequate theory of national economic phenomena were indeed lacking, it could be precisely for that reason that Operations Research is being called into

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\*For a diagnosis of the reasons for the absence of a satisfactory economic theory we may refer to [1] and [2], although we do not necessarily agree with the details of the therapeutic prescriptions offered therein.

action. Industrial and military Operations Research also has had to function without the benefit of a comprehensive accepted theoretical foundation. It has done this with great success, relying on the systematic utilization of a large body of only partly articulated and largely intuitive judgment by experts in the field. The standard operations research technique for such utilization is that of constructing an appropriate model of the situation; such a model—by introducing a precise structure and terminology—serves primarily as an effective means of communication, and thereby, through a feedback process, helps the expert to arrive at a clearer understanding of his subject-matter. The hope is that the same approach will meet with similar success in the area of national economic phenomena.

### 3. SIMULATION

The economist does not have, and cannot be expected to have, the precise and flexible means available to the physical scientist for testing his models experimentally. He can seldom, for example, experiment with an actual economy. He can, of course, make good use of experiments that are conducted by the economic system itself. That is, he can search out and observe situations in which the variables behave somewhat in the way he would expect them to behave in an actual experiment. In addition, he has other techniques available; one of these, "simulation," may provide a substitute means for exploring the implications of his theories and for comparing alternative hypotheses.

Simulation, although relatively new in wide-scale applications, is an established operations research technique, which uses quasi-experimentation in an artificial environment as a substitute for actual experimentation in the real world. The more the artificial environment is representative of the real world, that is, the better it simulates the relevant factors, the more reliably will a theory about the real world be tested in the simulative experiment and the easier will it be to apply insights gained to an understanding of the real situation under study.

The defects of simulation are that it is not ordinarily an efficient technique and that it yields only a quasi-empirical form of knowledge, inferior to the functional relationships built up through the more traditional approach of using an analytical model. Its outstanding virtue is that it can be used to tackle seemingly unmanageable or previously untouched problems where a traditional analytic formulation appears infeasible. Simulation is a device appropriate to use before one has an adequate theory, for it provides a means of using the intuition and advice of experts in a systematic fashion.

If a reasonably adequate simulation of the national economy of one of the "developing" countries were achieved, one might, for example, use it to examine a given development plan for consistency and technical feasibility. This would



be accomplished by observing within the model the effects of changes in the plan or of alternatives to it on such things as personal income or Gross National Product. Thereby a clearer insight into the nature of the underlying problems might be achieved and some ideas might begin to suggest themselves as to the sort of measures likely to be helpful in the real world.

#### 4. COMPUTER SIMULATION

A number of attempts have been made to simulate economic systems using high-speed digital computing equipment [for an example, see Ref. 3]. The ideal is to devise and program a model of the national economy under study that is complete in every important detail and which responds to stimuli provided by the operators exactly like the real one but on a much condensed time scale. Practical considerations, of course, impose many simplifications in the representation of the economy, requiring the use of aggregate variables, and the omission of many details. One possible approach is first to program separately the operation of each of the several sectors of the economy (consumer, industrial, financial, government, agricultural, labor, etc.), then to attempt to express their interrelationships and, finally, to try to tie the various sectors together in a combined program. Carefully done, this can lead to a computer program which represents the workings of an economy in much more realistic detail

than any model that can be examined by conventional analytic techniques.

Computer simulation is open to a number of objections:

- (i) Certain human factors, of great importance in the real world and hence not negligible, are extremely difficult to quantify; pride, loyalty, resistance to change, religious prejudice, etc. Elaborate models adapted for high-speed computers are not likely to take these factors into consideration with proper emphasis and subtlety.
- (ii) Assuming that our knowledge of economics is sufficiently firm so that in principle we know how to effect the simulation, it requires several years and the work of many people to program the model in realistic detail. It would thus not only be expensive but, more importantly, rigid. This inflexibility may be too high a price to pay for the precision with which a computer-programmed model represents an economy. The theory on which the model is based, after all, could not be expected

to be in completely final form but would inevitably call for successive corrections indicated by more up-to-date information or suggested by the learning process that parallels the application of the model. Such corrections would be likely to require elaborate and time-consuming changes in the computer program.

- (iii) The learning process just referred to is hindered rather than enhanced by the use of a computer model. For it is in the nature of a high-speed computing process that only highly selected stages of the computations are visible to an observer while most of the intermediate steps remain hidden in the "black box" of the machine. Hence the direct influence of variables upon one another, the knowledge of which is crucial in any intuitive reappraisal of a given theory, is generally not observable but must be inferred indirectly.

In view of these limitations, it is questionable whether, with our present knowledge of economic theory,

any computer simulation, no matter how elaborate, can answer questions such as:

(a) In initiating development, should emphasis be on investment and capital or on the attitudes and motivations of the people? Are there forces which can catalyze economic growth in an underdeveloped country?

(b) How does an underdeveloped country begin economic growth? Are limited capital, low productivity, inadequate rates of saving and investment the dominating constraints, or are they the attitudes and motivations of the people?

(c) What effects do government regulations in the form of taxes, subsidies, and restrictions on foreign investment and trade have on the economy?

(d) If the country is receiving foreign military assistance, how can the latter be modified, without significantly reducing military effectiveness, to generate substantially improved economic (and political) side-effects?

What is needed is some scheme that can give proper weight to the difficult-to-quantify social and political factors. One possibility is to introduce human players into the simulation.

## 5. GAMING

In analyses of major questions of public policy, it may well be worth the sacrifice of precision to gain other benefits. Among these would be a representation which at

least potentially—though perhaps with inadequate emphasis —included the political, economic, social, and military factors relevant to the analysis that might at first be overlooked or thought to be of insufficient importance. Another aspect which it would be desirable to take into account is the possibility of "feedback" of the type mentioned earlier which might lead one to want to modify the model in accordance with changes in the theory on which it is based. For the "developing" countries, where the situation is poorly structured and where we have little firm knowledge of the existing facts and relationships, a possible approach would be through an unsophisticated simulation, or "game," in which the various sectors of the economy would be represented by human simulators in the form of specialized experts. These would be expected, in acting out their roles, not so much to play a competitive game against one another but to use their intuition as experts to simulate as best they could the attitudes and consequent decisions of their real-life counterparts. It may well be necessary, in order to do justice to the intangible intricacies of the situation, to rely on the varied expertise of several specialists (e.g., an anthropologist in addition to an economist) for obtaining an acceptable degree of realism.

One objective of such an "unsophisticated" simulation would be to learn how to model an economy in the first place as well as to draw conclusions about the economy from an

existing model. Thus, the underlying game structure would, at least at first, be left flexible. Only when there is reasonably general agreement about the basic economic forces and trends would they be built firmly into the model; when there is not, we would attempt, in playing the game, to examine various economic hypotheses and rely on the considered expert judgment of the players to arrive at tentative conclusions. Thus the construction of the final model would become part of a mutual learning process, utilizing synthetic experience in lieu of actual experience when the latter is unavailable or insufficient.

Comparative rather than absolute results are the aim. Emphasis on this more modest aim provides an important hedge against mistaken assumptions about unknown parameters (especially those relating to human factors mentioned before) which are highly important in the real world.

The formal structure of a simulation exercise in the form of an operational game would automatically subject any model or theory of the operation of the countries' economies to detailed critical review. Since the environment of a game forces the players to take active roles, they are compelled to take specific and concrete actions in situations where a man sitting in his office or participating in a discussion around a conference table might fail to consider the full range of possibilities or to carry through the argument beyond the opening steps. It is easy to be vague in talking about theory or doctrine, but a game shares with the analytically formulated computer model the quality of concreteness—there

can be no vague moves in a well-formulated and well-run game. Moreover, controversial parts of the model which are likely to be buried and forgotten in a computer program remain visible.

Simulative gaming of the kind referred to above has been successfully employed in the past, though applied to different subject matters. We may mention the following three studies to illustrate the degree of sophistication of subject that can be captured by such relatively unsophisticated methods:

(a) An examination by C. Wolf and a staff of military and scientific experts of the effectiveness of military-assistance programs, based on limited-war gaming [4].

(b) Cold-war gaming, in which the players simulate the decisions of heads of government and thus jointly engage in modeling certain international relations. Such gaming was first used at RAND and has subsequently been carried out at M.I.T., at Northwestern University, and most recently at the Western Behavioral Institute at La Jolla [5], [6].

(c) Military research-and-development and procurement gaming, exemplified by the SAFE (Strategy and Force Evaluation) game developed at RAND, in which the players simulate the peacetime planning activities of the defense establishments of two major powers, their prime concern being the development, procurement, and operation of military weapon systems [7].

All of these efforts have certain features in common: The use of computers is minimal or even absent; reliance is on intuitive expertise of specialists; emphasis is on clearer problem formulation and on merely a first survey of possible solutions rather than on obtaining definitive answers.

#### 6. GAMING A NATIONAL ECONOMY

We would now like to indicate some suggestions as to how one might go about designing a simulative game model for the purpose of investigating economic problems on a national scale. It should be understood that these suggestions are tentative in nature and should be interpreted as merely indicative of the spirit in which we would like to see this problem approached and are approaching it ourselves.

The first question that arises in attempting to game a national economy is what roles are to be assigned to players. The decisions of the players are to simulate economic decisions in the real world, and thus are of two types: One is the deliberate decision by single individuals or groups acting as individuals, such as corporations, labor unions, the national government, parliament, etc. The other type of player decision simulates the aggregate effect of the multitude of decisions made by the members of an entire economic sector, such as agriculture, or industrial labor, or consumer goods manufacture. In the



first role, a player's decisions would be relatively unconstrained; in the second role, his "decisions" would not so much represent free acts of choice but estimates of how a certain economic sector might respond to a new situation.

For gaming purposes it would seem convenient to aggregate the economy into a relatively small number of sectors, say 8 to 10, and to let a player (or a weighted combination of players) correspond to each such sector; in addition, certain selected institutions may each be represented by a player. A possible breakdown of an economy into sectors might look as follows:

1. Agriculture
2. Mining
3. Labor
4. Power industry
5. Basic industry
6. Investment goods industry
7. Consumer goods industry
8. Services
9. Foreign commerce

In addition to the players representing these sectors of the economy, depending on the particular problem under study, there will have to be players representing the national government, or foreign investors, or the voting public, or even the revolutionary underground. In particular, a government player might be needed to study the effect of governmental regulation of the economy, a player representing foreign investment to determine the effect on the economy of specific allocations of such

investment. An alternative to handling these influences via the decisions made by the players assigned to these tasks is to leave these manipulations of the economy entirely to the control team running the game and to observe the effect of predetermined operations by the domestic government or the foreign investor through the reactions of the sector players.

Actually, of course, the precise line-up of players and what they are to represent depends critically on the particular economy being investigated and the question under study. A pregame phase in which the sectors and initial conditions are assigned somewhat arbitrarily and a few preliminary moves are planned is likely to be very helpful for the later more permanent formulation. During this phase, the important questions about aims and objectives which determine the whole character of the exercise can be discussed; for example: Is the aim in the development to become economically independent or to become prosperous—and what does that mean?

A next step in the construction of a game model would be to obtain an input-output matrix reflecting the initial annual flows of goods among the sectors of the economy. If no appropriate reliable statistics are available, estimates by qualified experts would have to take their place.

Next, and perhaps most difficult, would be the derivation of a production function for each sector, describing the annual production as a function of inputs (including labor) and investment. Here, in particular, heavy reliance on expert judgment would be almost inevitable. In cases where a general acceptable production function could not be obtained, it might be necessary—as the game proceeds—to defer to expert judgment in estimating the production resulting from a particular combination of inputs and investments. One would hope, in that case, that such casuistic assessment of production would eventually lead to the construction of general production functions.

Real-life factors affecting the economy in the form of taxation and of legislative supports and constraints would have to be reflected in the rules of the game. Similarly, natural effects (especially climatic) might be simulated by appropriate randomization schemes incorporated in the rules. These rules, incidentally, need not be static but can be modified from play to play or even during play.

Using either ready-made production functions or ad-hoc production estimates, the players could go through the motions of operating the economy over a series of annual cycles, each making periodic decisions on such things as prices to be charged for their products, purchases of inputs, and reinvestment of profits. In

this way one might hope to gain insight into the probable "normal" development of the unmanipulated economy, or to arrive at broad-brush productions of the effect of deliberate manipulation by legislative means or foreign investment.

Incidentally, players with definite beliefs regarding the workings of the economy would be able to examine their hypotheses quasi-experimentally, with the possibility of receiving salutary feedback from observing the consequences of their simulative actions. Conversely, a feedback in the opposite direction might be made observable in the case of economic policies which have a self-fulfilling component; for instance, a highly pessimistic policymaker might transmit his pessimism to the economy, and thus his beliefs might in fact influence the future course of the economy in a direction which would (unjustifiably) confirm his belief.

It should be noted that the resort to expertise in the construction, the playing, and the administration of such a game is not necessarily a liability but may be an asset. It does, admittedly, make the predictive quality of such an exercise very much a function of the quality of intuitive insight provided by the experts involved. On the other hand, by allowing for the introduction of judgment at every step, this approach provides an opportunity to take into account those human factors usually considered completely intangible. This is true

both of the player, who can let his economic decisions be influenced by his appraisal of the human effects of the simulated environment, and of the expert on the control team, who may be called upon to assess the effect of changed economic conditions on the productivity of labor in a given situation. For example, the success or failure of a plan may depend upon the assumptions about the mobility of the population and the flexibility in the allocation of materials. For a computer simulation, decisions about these things must be made in advance; in a game they can be made as the need arises.

A great disadvantage of a gaming exercise using human players is the time required to carry it out. In contrast, a computerized simulation can run through thousands of cases in far less time, once it has been programmed. The gaming process can be speeded up by introducing a computer for routine phases; whether this is economical or not depends upon the scale of the exercise.

We will readily admit that anyone using the approach we have described can set up some kind of a model in terms of which players can make moves analogous to the operations that take place in an economy. The results, however, may be meaningless or completely misleading if the model does not adequately simulate what it is supposed to. Yet even in the absence of the right numerical input values or of reliable functional relationships, as long as the right

qualitative features are present (e.g., dependencies, time lags, nonlinearities, and not readily quantifiable aspects such as human factors), experience in other fields indicates that a great deal of insight can be gained as to what modes of behavior are likely and what parameters are critical. It is a useful way to uncover alternatives and to organize arguments supporting a particular theory.

#### 7. CONCLUDING REMARKS

By way of a conclusion, we make the following observations.

In considering the possible application of Operations Research to problems of national planning, one should view any scheme proposed today which promises an immediately usable output with a great deal of skepticism. As expressed by Charles Hitch [8]:

Problems of national economic planning in underdeveloped countries are at least as intricate, as ridden with subtle political and sociological traps, as complicated by plural, interdependent, and conflicting objectives, and therefore as little amenable to current operations-research techniques, narrowly defined, as high-level problems of national security.

As an aid to counseling on high-level problems of national security, it is becoming increasingly clear that "current operations research techniques, narrowly defined" are not adequate. Piecemeal component optimizations and cost-

effectiveness comparisons of competing postures and strategies are extremely useful, but they must be supplemented by an over-all treatment in which emphasis is placed on an integrated simultaneous consideration of all the major relevant factors.

It seems reasonable, nevertheless, to look for an approach to national planning which has a capability of development to a point at which it can provide policy guidance in real situations. Our feeling is that the most promising approach is through some form of gaming. The more conventional analytic techniques or simulation by computer program, even though potentially they may have greater validity, are not sufficiently flexible. Moreover, even in cases where they provide correct guidance, they may still be lacking in conviction, for we have the uneasy feeling that any solution to a problem in this area exclusively formulated and solved by outsiders, using what is essentially a "black box," may not be readily accepted as a solution. By contrast, an important aspect of an unsophisticated simulation by the type of gaming we are advocating and trying to formulate, that has not been much exploited, is that the decision-maker or his representatives can actually participate.

In the area of national planning, the problems are likely to be ill-formulated and not of the type to which established optimization techniques can be applied without considerable preliminary work, if ever. The Operations

Research analyst usually tries, using mathematics or logical analysis, to help a client improve his efficiency in a situation in which everyone has a fairly good idea of what "more efficient" means. In contrast, here he is likely to be faced by problems where the difficulties lie in deciding what ought to be done or even in what the problems are rather than in simply how to proceed. In such a situation, far more attention must be devoted to establishing objectives, values, and criteria. The total analysis is thus a complex and untidy procedure, with little emphasis on mathematical models, no possibility of quantitative optimization over the whole problem, and great dependence on considered judgment.

To summarize further, the three main points of our argument are as follows:

1. Putting people in an appropriate environment provides a means of effective communication and thereby creates an opportunity for the systematic employment of the knowledge and insight of experts with diverse specialities.

2. A gaming approach establishes a possible means of providing "feedback" from the economy, resulting from the effects of the beliefs about it held by those who are trying to direct its course.



3. It provides a means of systematically taking into account relatively intangible factors which are compounded of economic, social, political, military and psychological considerations.

REFERENCES

1. Schoeffler, Sidney, The Failures of Economics: A Diagnostic Study, Harvard University Press, 1955.
2. Diefenbeck, James, "Phoenix Oeconomicus: Death of a Science, Birth of a Humanity," Ethics, July 1961.
3. Holland, E. P., "Simulation of an Economy with Development and Trade Problems," The American Economic Review, Vol. 52, No. 3, June 1962, p. 408.
4. Wolf, Charles, Jr., "Defense and Development in Less Developed Countries," Operations Research, Vol. 10, No. 6, November-December 1962.
5. Pool, Ithiel de Sola, "Cold War Modeling," Center for International Studies, Massachusetts Institute of Technology, Cambridge, Mass., in Proceedings of the Military Operations Research Symposia, Vol. 1, No. 1, Fall 1961.
6. Goldhamer, H., and H. Speier, "Some Observations on Political Gaming," World Politics, October 1959.
7. Helmer, Olaf, and T. A. Brown, SAFE: A Strategy and Force-Evaluation Game (U), The RAND Corporation, RM-3287-PR, October 1962, (Secret)
8. Hitch, Charles, "Operations Research and National Planning—A Dissent," Operations Research, Vol. 5, No. 5, October 1957, p. 719.